Northern Pike Movement Study in the Lower Milwaukee River and Harbor Using Sonic Tagging: 2011-2014

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Background

Northern pike (*Esox lucius*) are an ecologically important recreational native fish species in the lower Milwaukee River complex. They are a relatively long-lived iteroparous species which exhibit strong upstream spawning migratory behavior (Wawrzyn 2015).

Their population has been impacted and has severely declined due to harbor development and alteration of lower parts of the Milwaukee, Menomonee and Kinnickinnic Rivers which drain into Lake Michigan through the Milwaukee Harbor. Construction of several man-made barriers in the lower reaches and loss of wetland habitat are major causes of decline in the population. Fisheries surveys conducted by the Southern Lake Michigan fisheries unit in the last decade have documented adult and juvenile northern pike throughout the harbor, especially in the Menomonee Canals and downstream of the former North Avenue Dam (Figure 1). The results of numerous electroshocking surveys conducted annually in spring have indicated a congregation of mature northern pike immediately downstream of the former North Avenue Dam along their upstream migration route (Hirethota and Burzynski 2013, WDNR survey report). It is, however, unclear where these northern pike eventually move to for spawning. There is very limited suitable spawning habitat in the lower Milwaukee River. Occasionally, juvenile northern pike have been documented in the surveys suggesting spawning activity occurring in the area.

The main objectives of this project are to 1) assess the timing of northern pike movement upstream to potential spawning areas, 2) identify potential locations for spawning, 3) discover movement patterns after the spawning season, and 4) identify seasonal refuges in the summer and winter.

Methods

We used an electroshocking boat to capture adult northern pike in the spring. Generally, as soon as ice out, northern pike move upstream in the Milwaukee River and congregate below the former North Avenue Dam. We used this as the primary location to capture northern pike. We also collected pike from the lower Menomonee River. The tagging effort began in the fall of 2011 and continued through the spring of 2013. In total twenty northern pike – 9 female, 8 male and 3 unknown sexes – were surgically implanted with sonic tags (Vemco model V13-1L-A69-1303) (Table 3). In addition to a sonic tag, each fish also received a PIT tag and an external Floy® tag. The tagged pike ranged from 585 mm to 850 mm in total length, and 1,100g to 5,000 g in body weight.

Surgical procedure:

Adult northern pike were transported to the University of Wisconsin – Milwaukee, School of Freshwater Sciences (SFS) facility and held in a large flow-through tank. A few large chunks of salt were added to the tank to help recover the loss of salt/electrolytes. Each fish was anaesthetized in a separate tank using carbon dioxide (personal communication – Sue Marcquenski, former Fish Health specialist, WDNR). The anaesthetizing tank was continuously monitored for dissolved oxygen and pH levels using a Hanna Instruments HI® 9811-5 multifunction meter. The pH level was adjusted using baking soda to maintain the initial water pH at the time of capture. Surgical instruments, sutures and sonic transmitters were disinfected in Nolvasan® solution. Once fish equilibrium was lost, the fish was carefully removed in a sling net, weighed, measured and placed on the surgical table. The incision site on the body was dried and wiped with Carravet® gel. Using a sterile scalpel and grooved director, an incision (approximately ¾ inch) was made in the fish's abdomen slightly lateral to the ventral midline. While performing the surgery the gills were kept constantly irrigated with fresh water using a squirt bottle. Prior to inserting the tag into the fish body cavity, the sonic transmitter was removed from the Nolvasan® solution and rinsed with sterile water. The incision was quickly closed using 3-4 sutures of 3-0 Ethilon black mono nylon, 18" cutting needle PS-1 (Figures 2-4). Injectable oxytetracycline 200 mg was dispensed along the incision line and at the suture points to help protect the fish from infection. The process from the time of making the incision to closing with sutures took approximately four minutes. Further, each fish was tagged with a numbered Floy® tag with our DNR office address and implanted with a PIT tag. After the surgery, the fish were transferred to a circulating water recovery tank with 0.5% to 0.9% salt solution. The fish were held in the recovery tank for 45 minutes to 1 hour before transporting them to the release locations.

Of the twenty northern pike tagged, three were tagged in the fall of 2011, 10 in the spring of 2012, four in the fall of 2012 and three in the spring of 2013 (Table 3). Six tagged fish (three in the fall 2011 and three in the spring 2013) were released at the slip near the UWM School of Freshwater Sciences. Four tagged fish were released at the Riverfront Ramp in fall 2012. Ten tagged fish were released below the former North Avenue Dam in spring 2012. (Table 4). Although the preferred location of release was below the former North Avenue Dam (so that fish would be released in the same location in which they were captured), fish that were released at the SFS slip or the Riverfront Ramp were released there due to concerns over transporting the fish longer distances.

Data gathering:

The data on the fish movement were recorded by installing receivers (Vemco® model VR2W 69 kHz; Figure 5) at various locations (Tables 1 and 2) in the study area (Figure 1) for continuous recording of tagged fish. Continuous temperature recording thermistors were installed along with the receivers (onset® HOBO® water Temp Pro V2 Logger). Since we had a limited number of receivers at our disposal, to maximize the study area covered at any given time, we moved the receivers around from place to place instead of having fixed stations throughout the year. The maximum number of receivers placed at any given time was eleven in November 2012. In general, the number of receivers at any given time varied from four to eleven between January

2011 and December 2014. In total, data were collected from twenty locations in the study area. The receiver deployment locations included five general areas, 1) Milwaukee River upstream sites – Kletzsch Park, Estabrook Dam, Estabrook Falls, Chambers Street and Spawning Reef; 2) Milwaukee estuary inner harbor – Menomonee River at 35th Street, Menomonee River at 6th Street, Milwaukee Metropolitan Sewerage District (MMSD), Confluence of South Menomonee and Burnham Canals, Burnham Canal, North Swing Bridge, mouth of the estuary at Sail Loft and the Kinnickinnic River; 3) Milwaukee Estuary outer harbor – Outer Harbor, Summerfest Lagoon and Veterans Park; 4) McKinley Marina and 5) South Shore – South Shore Marina and South Shore Break wall (Figure 1).

The receiver locations were chosen to document spawning migrations (Milwaukee River upstream sites), use of the Milwaukee Harbor estuary as overwintering habitat (Milwaukee estuary inner harbor), and potential cool-water refugia (Milwaukee estuary outer harbor). The North Avenue dam spawning reef, MMSD and Summerfest Lagoon sites were chosen as long-term deployment sites because each represented unique habitat type, and they afforded relatively secure locations for the receivers. Shorter-term deployments were used to document habitat use on a finer scale or seasonal basis.

The data were downloaded periodically to a laptop computer for compiling and analysis using VUE (Vemco User Environment; Version 2.0.6-20130212) software. All data were subsequently exported from the VUE software into Excel files for analysis. Data files were also imported into ArcGIS for generation of movement and distribution maps.

Results

A total of twenty northern pike were implanted with sonic tags over a period of fall 2011 through spring 2013. The fish that were tagged and released were collected primarily from two areas – the lower Menomonee River and the lower Milwaukee River. Once the fish were surgically implanted with sonic tags and recovered from the surgery they were released back in to the system at three different locations (Figure 1). The majority of them (10 fish) were released in the Milwaukee River just below the former North Avenue Dam. Six fish were released at the slip next to the UWM School of Freshwater Sciences, and the remaining four were released at the Riverfront Ramp near the mouth of the estuary.

The number of days that the tagged northern pike were detected in the system varied from two days to 811 days (Table 4). Of the twenty northern pike tagged, at least thirteen fish were detected for more than 100 days, of which nine fish were detected in the spring following the tagging event. Four fish were present longer than five hundred days in the system, and thus detected over two consecutive springs. Even though our sample size was small, we had good numbers of tagged fish survive for extended periods of time. A few fish that were detected for a very short time were either fished out or might have moved out of the system.

Of the twenty fish tagged, we used data from the thirteen fish that were detected longer than 100 days from the day of release post implanting for this analysis. Movements of these thirteen fish are summarized in graphs below (Figures 11-23), detailing when these fish were detected (by

month, for each year) as well as the locations in which these fish were found (by specific receiver). For each month of detection, we broke down the percentage of detections ("pings") of each individual fish by location.

For example, the northern pike implanted with transmitter 50.350 was detected in the system for a total of 811 days over three years, beginning in March 2012 (Figure 17). Pike 50.350, a female, was captured in the Milwaukee River on March 15, 2012, tagged, and released the same day in the Milwaukee River below the former North Avenue Dam. This fish was detected at the spawning reef near the former dam for the remainder of March and a portion of April. Sometime in April, pike 50.350 moved to the Summerfest Lagoon, where it was detected in April, May, June, July, and approximately 90% of August. This fish was also detected in Veterans Park in August, but was only detected at the Summerfest Lagoon in September. This fish moved significantly more during October and November than during the previous months; in October, approximately 39% of detections occurred in the Summerfest Lagoon, although this fish was also detected at the Kinnickinnic River, Sail Loft, and the spawning reef. In November, pike 50.350 was found at the McKinley Marina, Sail Loft, the Summerfest Lagoon, and Veterans Park. This fish was not detected again until March 2013, when it was detected back at the spawning reef. Pike 50.350 seemed to move more in the following months than was seen the previous year; while this fish spent most of April at Sail Loft and most of May, June, and July at the Summerfest Lagoon, it was also detected at Veterans Park and the McKinley Marina. In August and September, it was detected at Veterans Park, the Summerfest Lagoon, and McKinley Marina. In October, this fish was detected primarily in the Summerfest Lagoon, as well as Sail Loft and Veterans Park. In November, this fish was detected staying around Sail Loft, and in December, the Summerfest Lagoon. This fish was not detected again until February 2014, when it was detected in the Menomonee River, both west of 6th street and at MMSD. It was not detected in March, but was detected in April at the spawning reef, Summerfest Lagoon, Veterans Park, and UW-Milwaukee School of Freshwater Sciences. This fish moved back to the Summerfest Lagoon in May. The final detections of this fish occurred in June 2014, where it was primarily detected at the Summerfest Lagoon, as well as Veterans Park.

Similarly, the northern pike implanted with transmitter 33.269 was detected in the system for a total of 584 days over three years beginning on October 2012 (Figure 20). Pike 33.269, a male, was captured in the Menomonee River on October 24, 2012, tagged, and released the same day at Riverfront Ramp. This fish was detected in the area at Sail Loft for the remainder of October and most of November. Pike 33.269 was also detected in November in the Menomonee River at MMSD as well as in the Kinnickinnic River. In December, this fish was detected primarily in the Burnham Canal and at the confluence of canals, though it was detected for a small percentage of time in the Menomonee River at MMSD. In January and February 2013, pike 33.269 was detected at the same four locations – the Burnham Canal, the confluence of canals, the Menomonee River at MMSD, and the Menomonee River west of 6th street. This fish moved quite a bit in April, when it was detected at the previous four locations as well as the Kinnickinnic River, Sail Loft, the South Shore Marina, and Veterans Park. Almost 70% of detections in May occurred in Veterans Park; this fish then spent a small percentage of time in the Summerfest Lagoon, but primarily McKinley Marina. This fish was only detected at McKinley Marina in June. Most of July found this fish at Veterans Park, with some time spent at McKinley Marina. In August, September, and October, this fish moved between McKinley

Marina, Summerfest Lagoon, and Veterans Park. In November, this fish was detected at Summerfest Lagoon, Veterans Park, and McKinley Marina, but moved up the Menomonee River and was detected primarily in the Menomonee River west of 6th street. In December, the fish was detected primarily in the Menomonee River at MMSD, though it also was detected at Veterans Park, UW-Milwaukee School of Freshwater Sciences, and the Menomonee River west of 6th street. This fish appeared to spend most of its time in January in the Menomonee River, but spent most of February, March and April in the Summerfest Lagoon and near Veterans Park. The final detections of this fish occurred in June 2014, where it was detected at the South Shore Marina.

While these two northern pike moved around frequently for the duration of their detection, some fish were detected in very few locations, such as the northern pike implanted with transmitter 42.730 (Figure 11), which was only detected at two locations in the Menomonee River. These graphs were used to analyze movement patterns of all northern pike combined (Figures 7-10).

Assessing the timing of northern pike movement upstream to potential spawning areas and identifying potential locations for spawning:

In 2012, when receivers were deployed in multiple locations all year (Table 1), all tagged northern pike combined spent 100% of the time in the spawning reef below the former North Avenue Dam in February (Figure 8). It is important to note than in February 2012, likely only two fish with sonic tags implanted were in the system. Three fish were tagged in October 2011, but one was only detected for two days. Of the two remaining, both were captured in the Menomonee River and released in the slip at the UW-Milwaukee School of Freshwater Sciences (Table 4). These fish were detected in 2011, but not in the spawning reef (Figure 7). Therefore, it is possible that these two fish were moving upstream in February for the purpose of reaching the spawning reef.

Some fish were also detected at the spawning reef in March (Figure 8). However, eight fish were tagged in March 2012 and released below the North Avenue Dam, so these fish could have stayed in the area while adjusting to release. They were caught in the same area as the release location, and thus may have been in the area for spawning before capture. Eleven of the thirteen fish used in this analysis were tagged prior to 2013, when all tagged fish spent 100% of detection time at the spawning reef in March (Figure 9).

One receiver was deployed at Kletzsch Park in 2012 (Table 1). River habitat in Kletzsch Park indicates a possible spawning location, but northern pike were not detected here, although the receiver was only deployed at this location for three months. Fish were detected downstream of Kletzsch Park at Estabrook Falls in 2012, so it is possible conditions at Kletzsch (such as river level and flow) were not conducive to fish passage during this time.

While we were not able to completely address the questions laid out in this objective, we were able to gather further information regarding the timing of northern pike movement upstream to potential spawning areas and identify one potential spawning location.

Movement patterns of northern pike and identifying seasonal refuges:

For this portion of the analysis, detection data from the thirteen northern pike detected longer than 100 days were combined to examine their movement pattern as a group in the study area.

As referenced above, the three northern pike tagged in October 2011 were released after the implantation at the slip near the UWM School of Freshwater Sciences. These fish spent the majority of their time in the Menomonee River in November and December (Figure 7). They continued to stay in the area through January 2012 (Figure 8). The water in this area stays warmer in the winter months due to warm water discharge by the Valley Power Plant, hence providing winter refuge for the pike. In addition, the warmer water also attracts many forage fish species for the pike to feed on. These pike moved upstream on the lower Milwaukee River in February 2012 to the North Avenue spawning reef area, and spent the entire month there, perhaps indicating early spawning migration. Early February showed spikes in mean daily discharge (Figure 6). The flow of fresh water might have triggered the fish movement upstream.

We implanted ten more northern pike in March and April 2012 and released all of them in the lower Milwaukee River just below the former North Avenue Dam. These fish joined the 2011 tagged fish in the system. Besides detecting tagged pike near the spawning reef in March and April, they also spent a significant amount of time in the Summerfest Lagoon, McKinley Marina, and South Shore Marina (Figure 8). Fish were also detected near Estabrook Falls on the Milwaukee River and all the way up to the 35th street bridge on the Menomonee River (Figures 8-23). This is a rather large range covered in only those two months. In late spring and early summer (May-June) northern pike moved around from the North Avenue spawning reef to the outer harbor and spent a significant amount of time in the outer harbor. Later in the summer (July-August-September) as the water temperature gets warmer, the pike appear to be spending more time in the deeper, cooler waters of Summerfest Lagoon, Veterans Park and McKinley Marina (Figures 9, 13-23). Although 2012 was a very dry year (Figure 6), with low flows and warmer than average water temperatures, the tagged northern pike made a short trip to the spawning reef in July. In the fall, they appear to be moving back from the outer harbor to the Menomonee River as seen by the sizable amount of time spent near the Sail Loft site in October-November and settling down in the inner harbor area for the winter, until February 2013 (Figure 9).

Three additional northern pike were tagged in April of 2013. Although no fish were tagged in 2014, the receivers were deployed all year, as the sonic tags implanted had a lifespan of two years. In 2014, northern pike that were detected spent significant amounts of time in the Menomonee River and Summerfest Lagoon in January and February, and in the UWM School of Freshwater Sciences slip in March-July (Figure 10).

Discussion and Challenges

While there are conclusions that can be drawn about northern pike movement and habitat use from the observations made in this study, there are also gaps in data that should be addressed. Seven tagged northern pike were left out of the analysis, as they were detected less than 100 days through the duration of the study. One possible explanation for lower detection days is mortality. Another explanation relates to the limited number of receivers available to us for the

study, meaning it was not feasible to have a sonic receiver deployed at all locations for the duration of the study. There were also three receivers lost throughout the study.

In addition, there were large periods of time when northern pike were not detected and may have been assumed a mortality loss until resurfacing a year later (Figure 15). Aside from moving receivers to different locations, this could suggest technical issues.

Finally, it is difficult to make generalizations about habit use when it became clear there was no pattern of movement that applied to all tagged northern pike. One pike, for example, spent nearly the entirety of March through December 2012 in the Summerfest Lagoon (Figure 13). This same fish was detected again in May and June 2013 and April and May 2014 in the Summerfest Lagoon. Another fish was only detected at Sail Loft (Figure 21), while some fish were detected in six or more locations, such as northern pike 50.350 and 33.269 as detailed above (Figures 17 and 20). Despite these challenges, we were able to determine multiple locations with varying habitat uses for northern pike and establish areas of interest for further study. In general, northern pike in our study used areas of the Milwaukee Estuary outer harbor (such as Summerfest Lagoon, McKinley Marina, and Veterans Park) most frequently during the summer months, potentially as a cool-water refuge (Figure 9). Areas of the Milwaukee Estuary inner harbor, such as SailLoft and the UW-Milwaukee SFS slip, were frequently used by northern pike during the winter months, potentially as overwintering habitat (Figures 16-18). Many pike spent late winter and early spring in either the inner harbor or in the Menomonee and Milwaukee Rivers. Due to our study limitations, it is not clear if northern pike were returning to the rivers in late winter and early spring due to spawning site fidelity or another reason. For example, northern pike 42.730 (Figure 11) was captured in the Menomonee River, released in the Milwaukee inner harbor at the UW-Milwaukee SFS slip, and returned to the Menomonee River. However, there were fish captured in the Milwaukee River that returned to both rivers, such as northern pike 50.347 (Figure 14) and fish captured in the Menomonee River that returned to both rivers, such as northern pike 42.731 (Figure 12). Some of these locations, such as SailLoft, were not always equipped with sonic receivers. When sonic receivers were deployed, northern pike were detected there. Focusing on the Milwaukee and Menomonee Rivers as well as river confluences and the inner Milwaukee harbor would be ideal locations for further study due to these results.

Table 1. Distribution and placement of Vemco receivers in the lower Milwaukee River and harbor from January 2011 through December 2012. Red cells indicate locations where receivers were deployed at a given point in time.

	2011			2012												
Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Menomonee River - MMSD															
Spawning Reef															
Estabrook Falls															
Veterans Park															
Summerfest Lagoon															
Sail Loft															
North Swing Bridge															
South Shore Marina															
Menomonee River at 35th Street															
McKinley Marina															
Kinnickinnic River															
Kletzsch Park															
South Shore Breakwall															
Menomonee River upstream of 6th Street															
Burnham Canal															
Confluence of South Menomonee and Burnham Canals															
UW-M School of Freshwater Sciences															

Table 2. Distribution and placement of Vemco receivers in the lower Milwaukee River and harbor from January 2013 through December 2014. Red cells indicate locations where receivers were deployed at a given point in time.

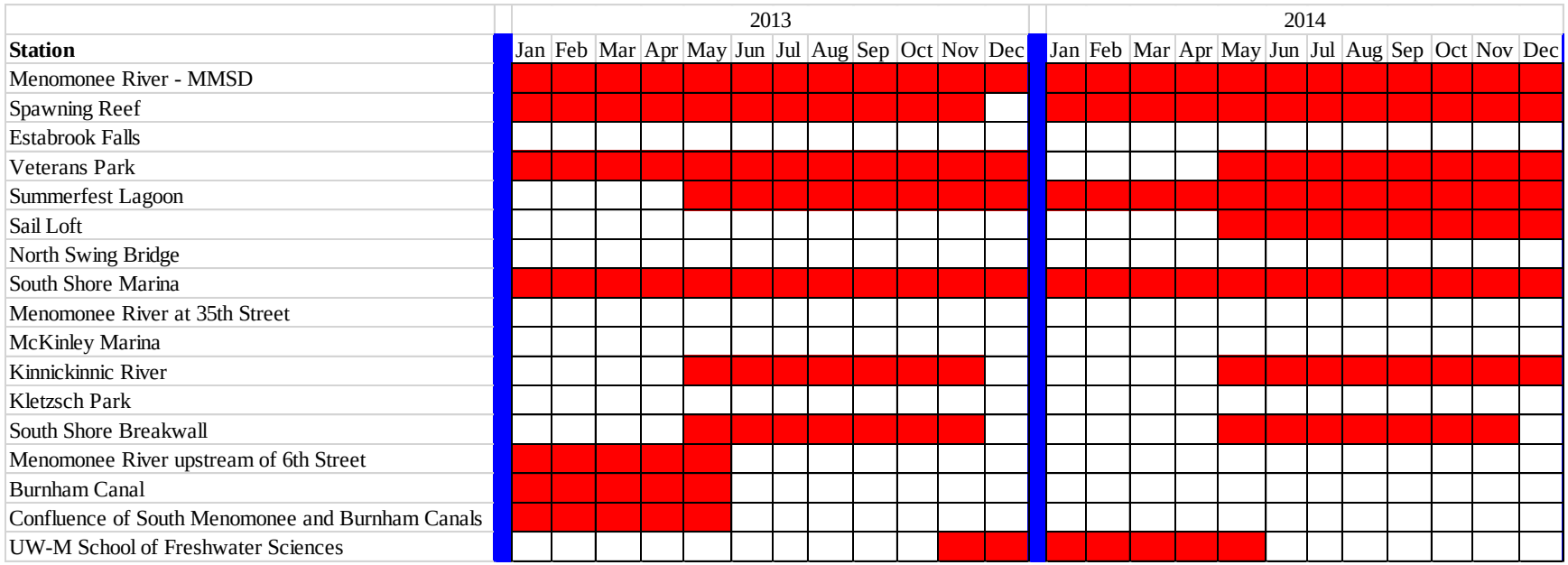

Table 3. The table below gives the list of sonic tags implanted in northern pike in 2011, 2012 and 2013.

Date	Capture Location	Length (mm)	Weight (g)	Sex	Condition	Sonic Tag	Floy Tag	PIT tag
10/26/2011	Menomonee River	745		U	U	42.729	1673	
10/26/2011	Menomonee River	655		U	U	42.730	1672	
10/26/2011	Menomonee River	585		U	U	42.731	1671	
03/15/2012	Milwaukee River	685	2700	F	G	50.344	88	*40486
03/15/2012	Milwaukee River	645	2100	M	R	50.345	89	*22153
03/15/2012	Milwaukee River	765	4200	F	R	50.346	90	*74313
03/15/2012	Milwaukee River	750	3200	M	R	50.347	91	*54844
03/15/2012	Milwaukee River	782	4200	M	R	50.348	92	*85149
03/15/2012	Milwaukee River	660	2500	F	G	50.349	93	*51943
03/15/2012	Milwaukee River	715	3700	F	G	50.350	94	*34078
03/15/2012	Milwaukee River	640	2200	F	G	50.351	95	*33060
04/03/2012	Milwaukee River	850	5000	F	G	50.352	286	*43259
04/03/2012	Milwaukee River	627	2100	M	R	50.353	287	*49908
10/24/2012	Menomonee River	605	1500	M	U	33.267	1164	**10313
10/24/2012	Menomonee River	643	2000	F	U	33.268	1165	**93020
10/24/2012	Menomonee River	601	1500	M	U	33.269	1166	**09837
10/24/2012	Menomonee River	596	1100	M	U	33.270	1167	*94184
04/03/2013	Milwaukee River	812	5100	F	G	33.271	1612	**12806
04/03/2013	Milwaukee River	778	3900	F	G	33.272	1613	*97286
04/03/2013	Milwaukee River	672	2300	M	G	48.629	1614	**27003

* PIT tag prefix – 9851210280
** PIT tag prefix - 9851210281

Table 4. Northern pike sonic tagging data on locations of release of fish and number of days each fish was tracked, 2011-2014.

Fish ID/Tag #	Capture location	Release location	Date released	Dates of first and last detection	# of days detected at large
42.729	Menomonee River	UWM SFS	10/26/2011	10/26/2011 - 10/28/2011	2
42.730	Menomonee River	UWM SFS	10/26/2011	11/12/2011 – 06/11/2012	211
42.731	Menomonee River	UWM SFS	10/26/2011	10/26/2011 – 03/24/2012	150
50.344	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 04/28/2012	44
50.345	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 05/31/2014	806
50.346	Milwaukee River	Below North Avenue Dam	03/15/2012	03/16/2012 – 03/20/2012	4
50.347	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 11/19/2012	248
50.348	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 05/25/2013	435
50.349	Milwaukee River	Below North Avenue Dam	03/15/2012	03/17/2012 – 01/05/2013	294
50.350	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 06/05/2014	811
50.351	Milwaukee River	Below North Avenue Dam	03/15/2012	03/15/2012 – 05/29/2013	440
50.352	Milwaukee River	Below North Avenue Dam	04/03/2012	05/23/2012 – 07/13/2012	51
50.353	Milwaukee River	Below North Avenue Dam	04/03/2012	04/17/2012 – 07/14/2012	88
33.267	Menomonee River	River Front Ramp	10/24/2012	10/24/2012 – 11/190/2012	17
33.268	Menomonee River	River Front Ramp	10/24/2012	10/24/2012 – 05/08/2014	561
33.269	Menomonee River	River Front Ramp	10/24/2012	10/24/2012 – 06/01/2014	584
33.270	Menomonee River	River Front Ramp	10/24/2012	10/24/2012 – 09/11/2013	322
33.271	Milwaukee River	UWM SFS	04/03/2013	04/07/2013 – 04/26/2013	19
33.272	Milwaukee River	UWM SFS	04/03/2013	04/04/2013 – 09/21/2013	170
48.629	Milwaukee River	UWM SFS	04/03/2013	04/05/2013 – 02/07/2014	308

Figure 1. Study area including lower reaches of Milwaukee, Menomonee, and Kinnickinnic Rivers, Burnham and South Menomonee Canals, inner and outer harbor, and South Shore Marina.

Figure 2. Sonic tag (Vemco model V13-1L-A69-1303) that was inserted into the abdominal cavity of northern pike.

Figure 3. Preparing fish for surgical insertion of sonic tag into the abdominal cavity.

Figure 4. Applying sutures to close the incision where the tag is inserted.

Figure 5. Vemco sonic receiver (Vemco model VR2W 69kHz) set up to install at index sites.

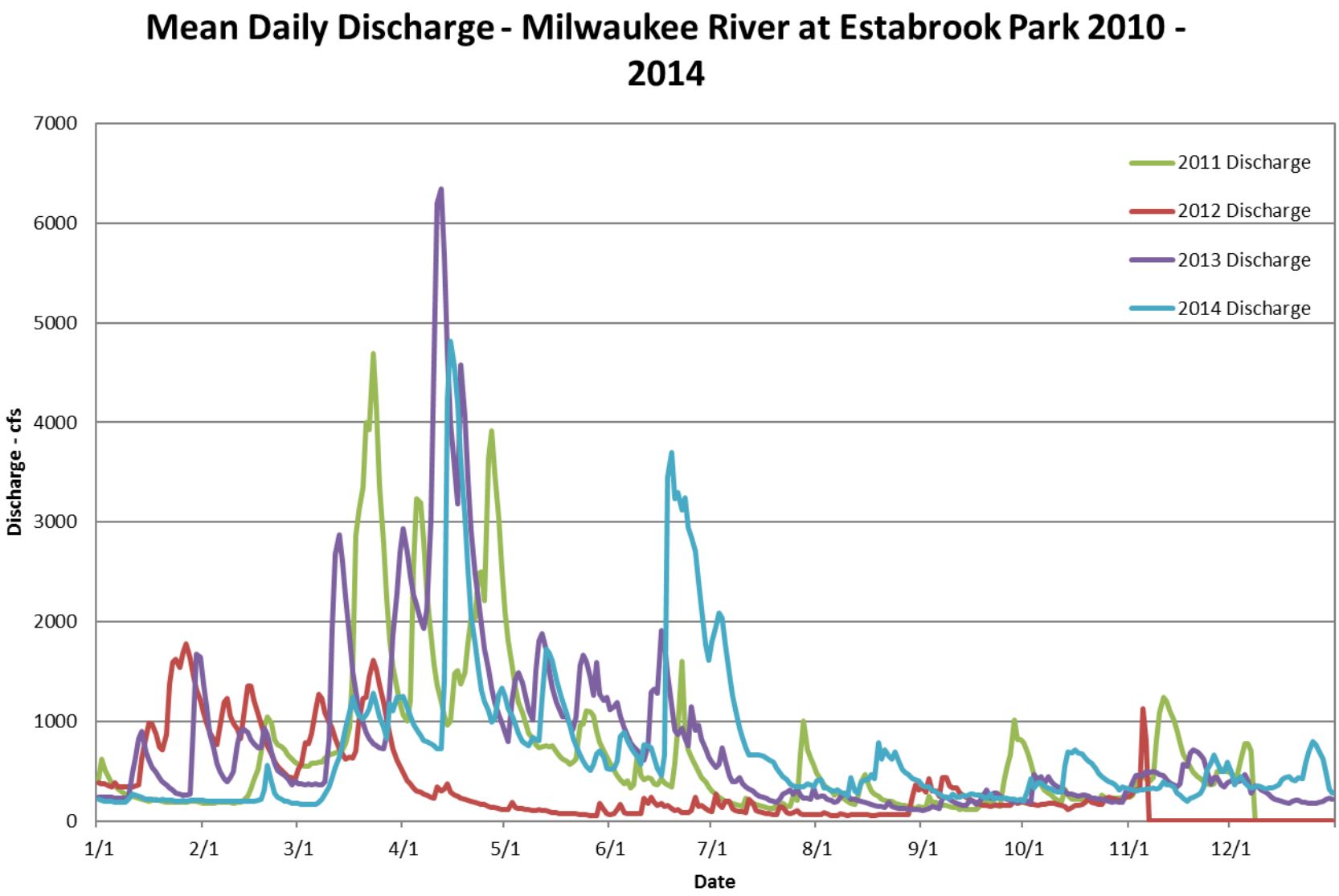

Figure 6. Mean daily discharge – Milwaukee River at Estabrook Park from 2010 – 2014.

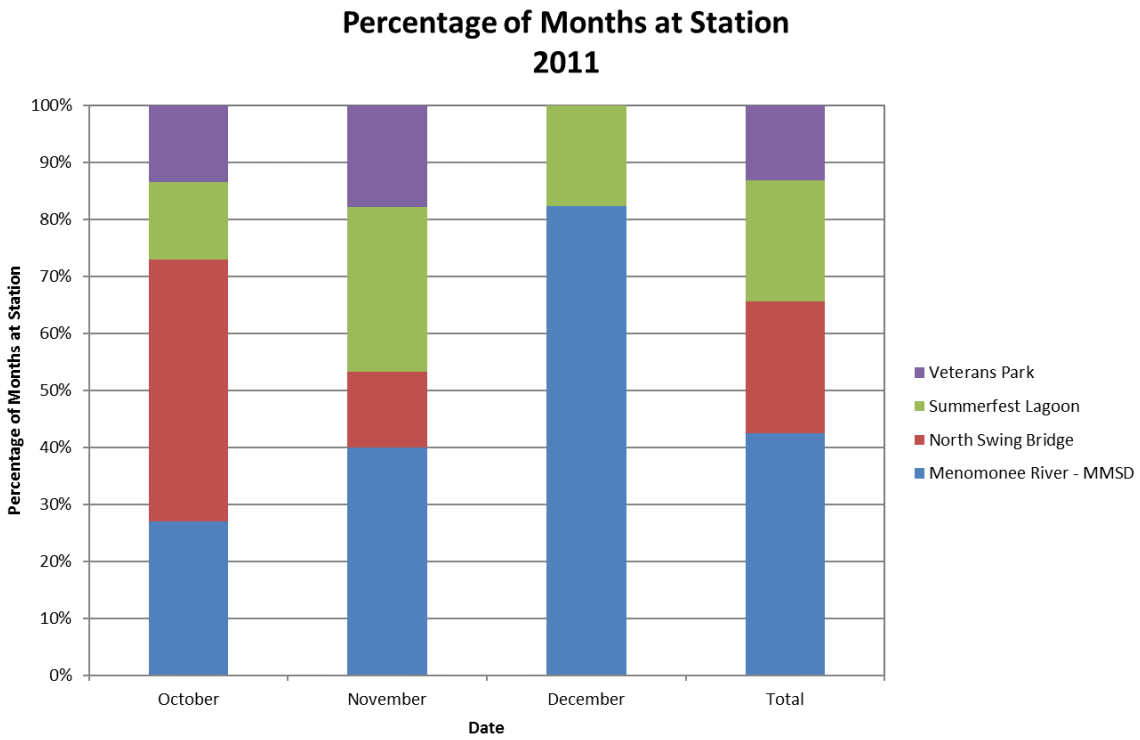

Figure 7. Percentage of months from October through December 2011 spent by all tagged northern pike combined at each station.

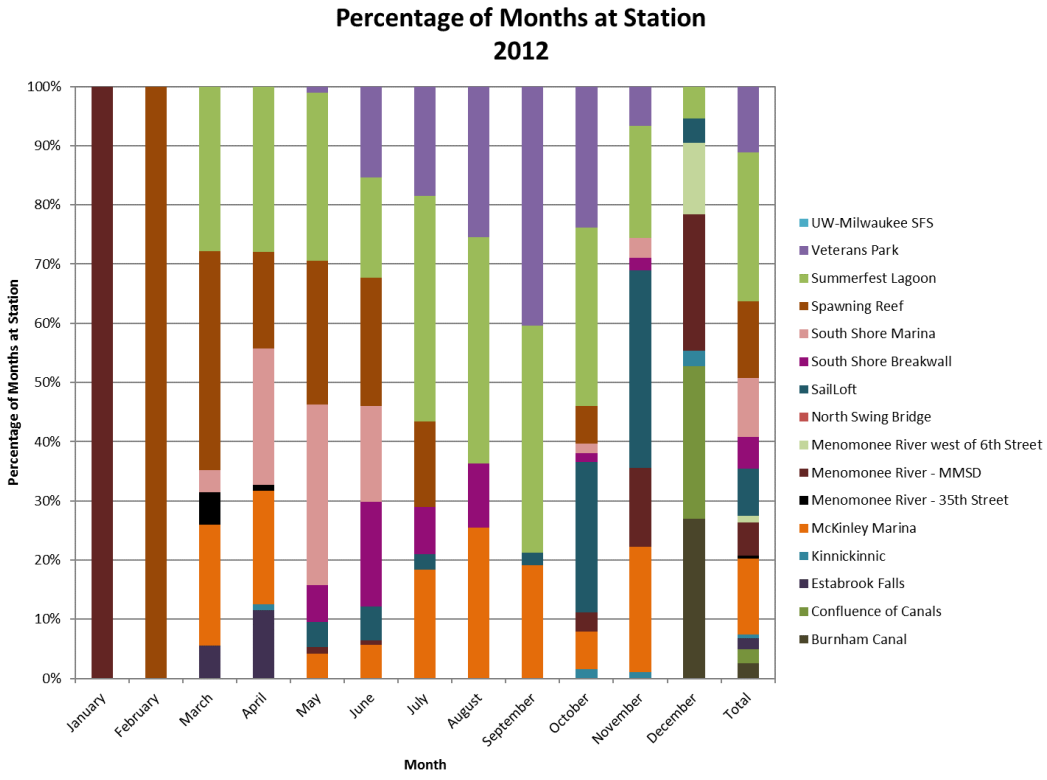

Figure 8. Percentage of months from January through December 2012 spent by all tagged northern pike combined at each station.

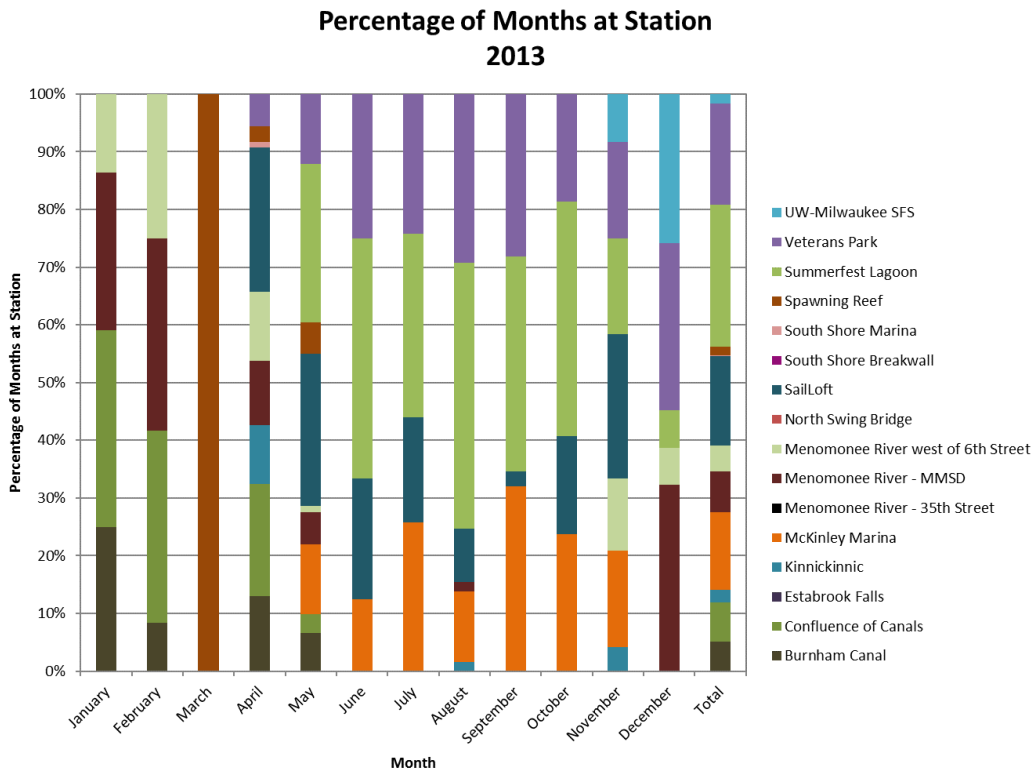

Figure 9. Percentage of months from January through December 2013 spent by all tagged northern pike combined at each station.

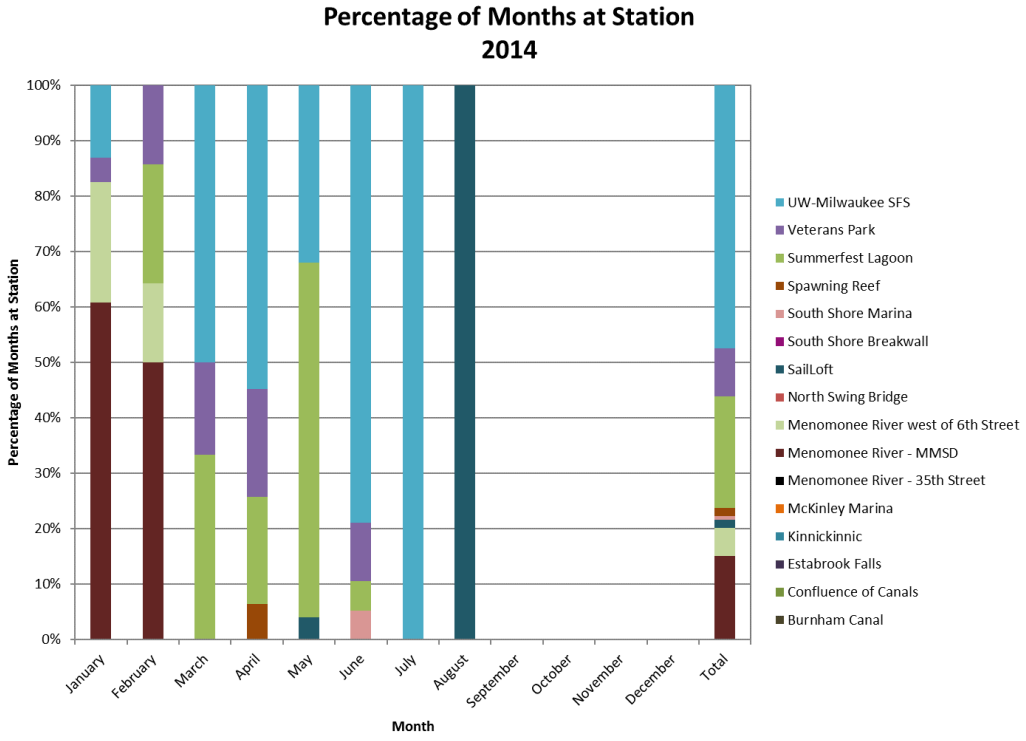

Figure 10. Percentage of months from January through December 2014 spent by all tagged northern pike combined at each station.

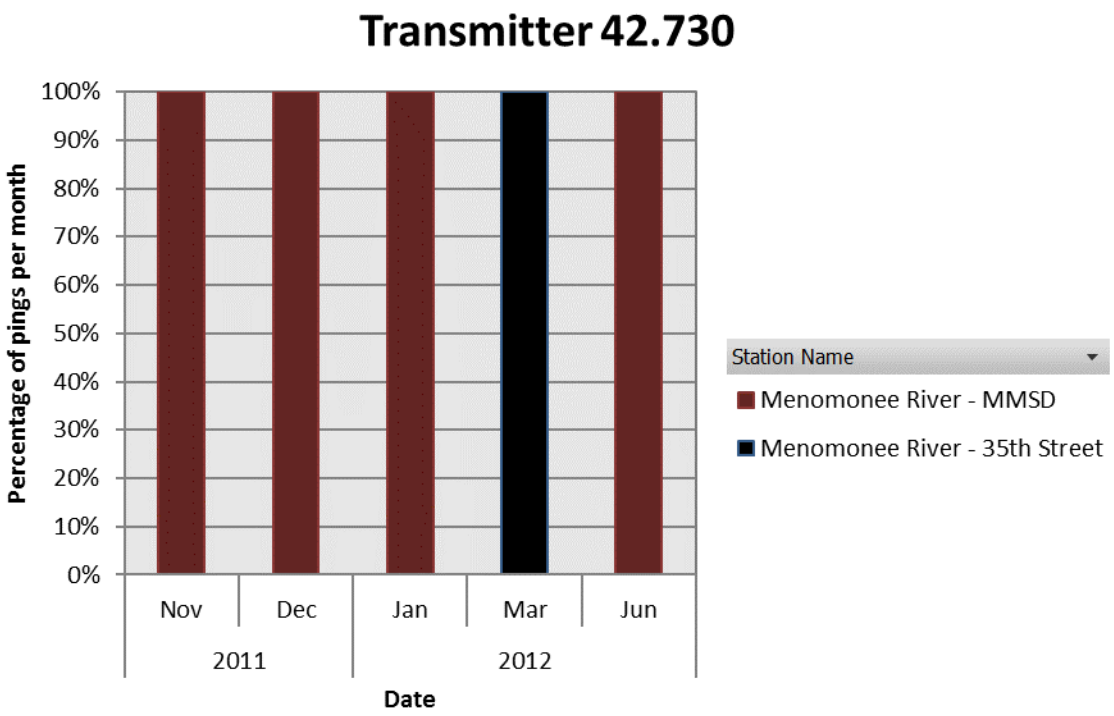

Figure 11. Movement of northern pike with transmitter 42.730 in 2011 and 2012.

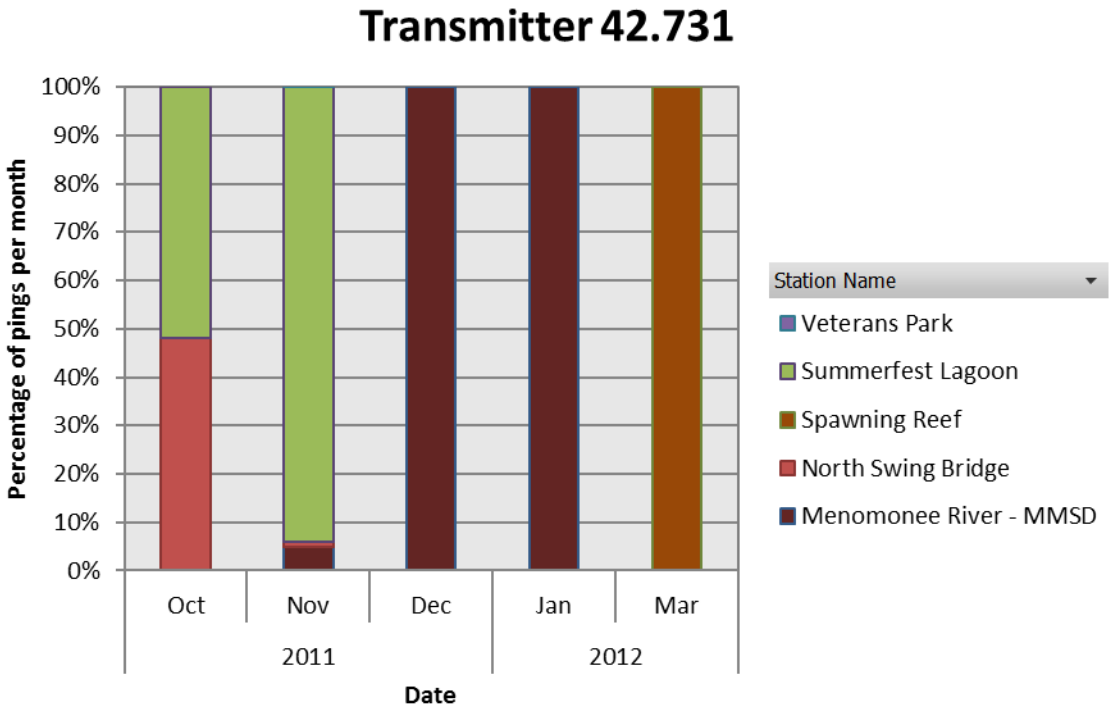

Figure 12. Movement of northern pike with transmitter 42.731 in 2011 and 2012.

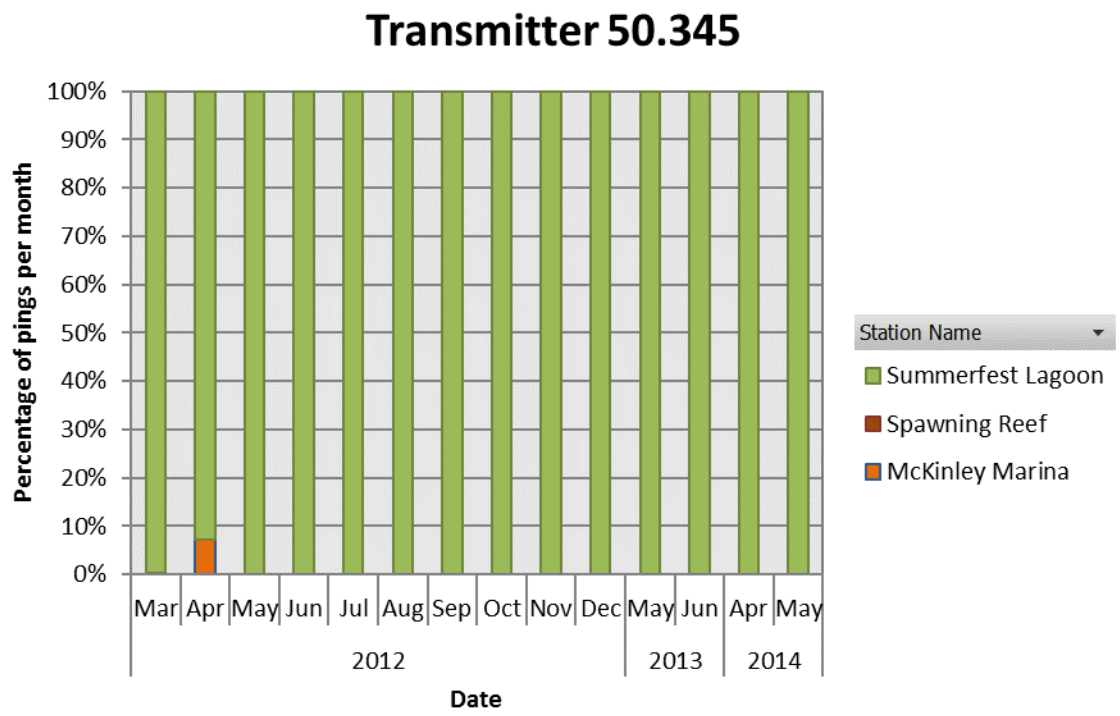

Figure 13. Movement of northern pike with transmitter 50.345 in 2012, 2013 and 2014.

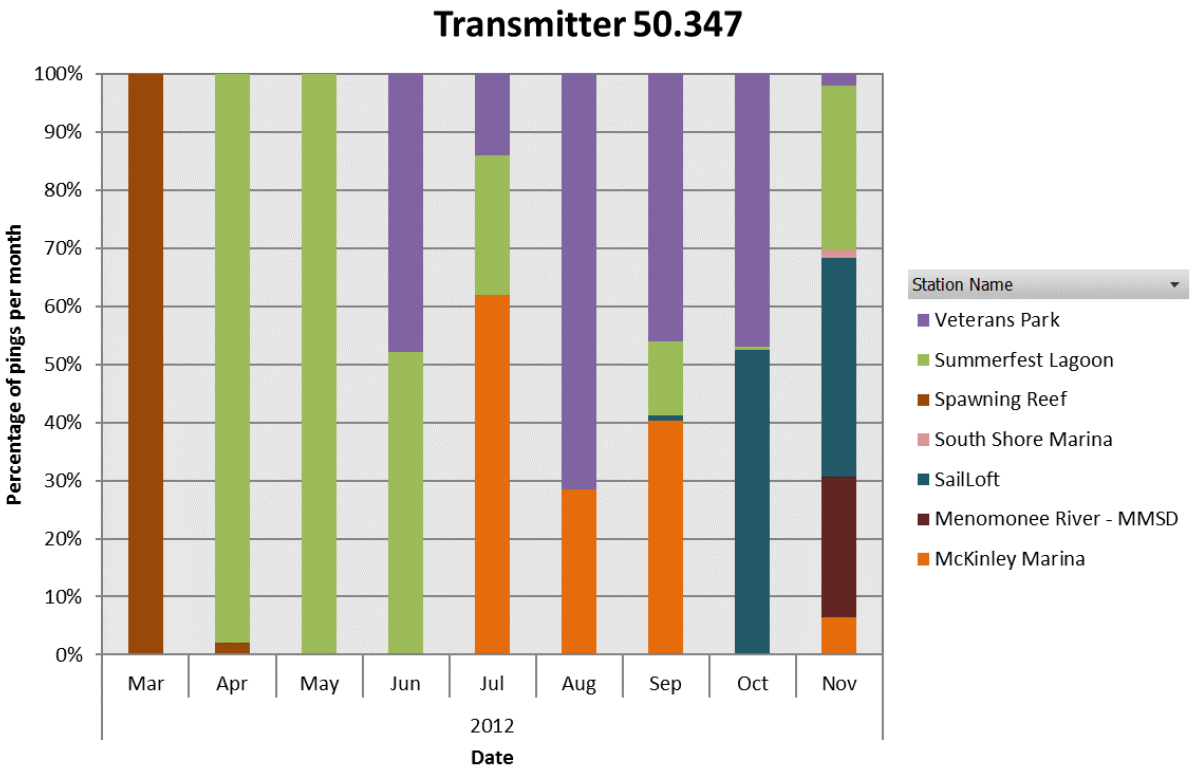

Figure 14. Movement of northern pike with transmitter 50.347 in 2012.

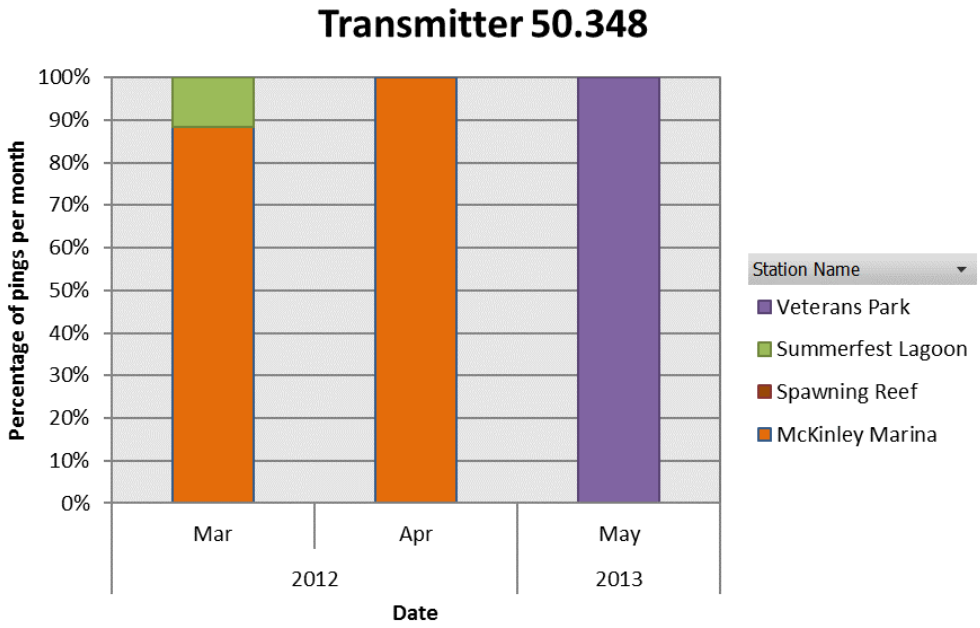

Figure 15. Movement of northern pike with transmitter 50.348 in 2012 and 2013.

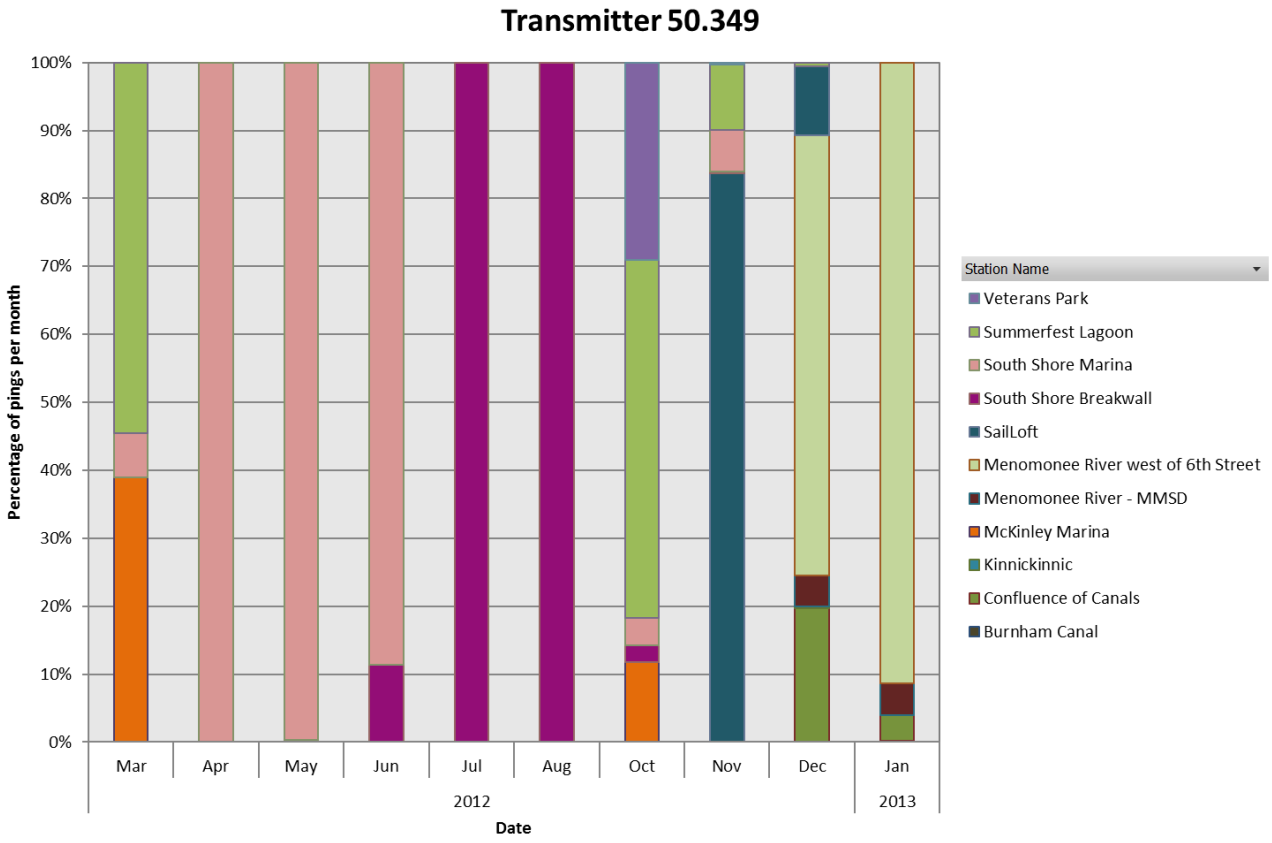

Figure 16. Movement of northern pike with transmitter 50.349 in 2012 and 2013.

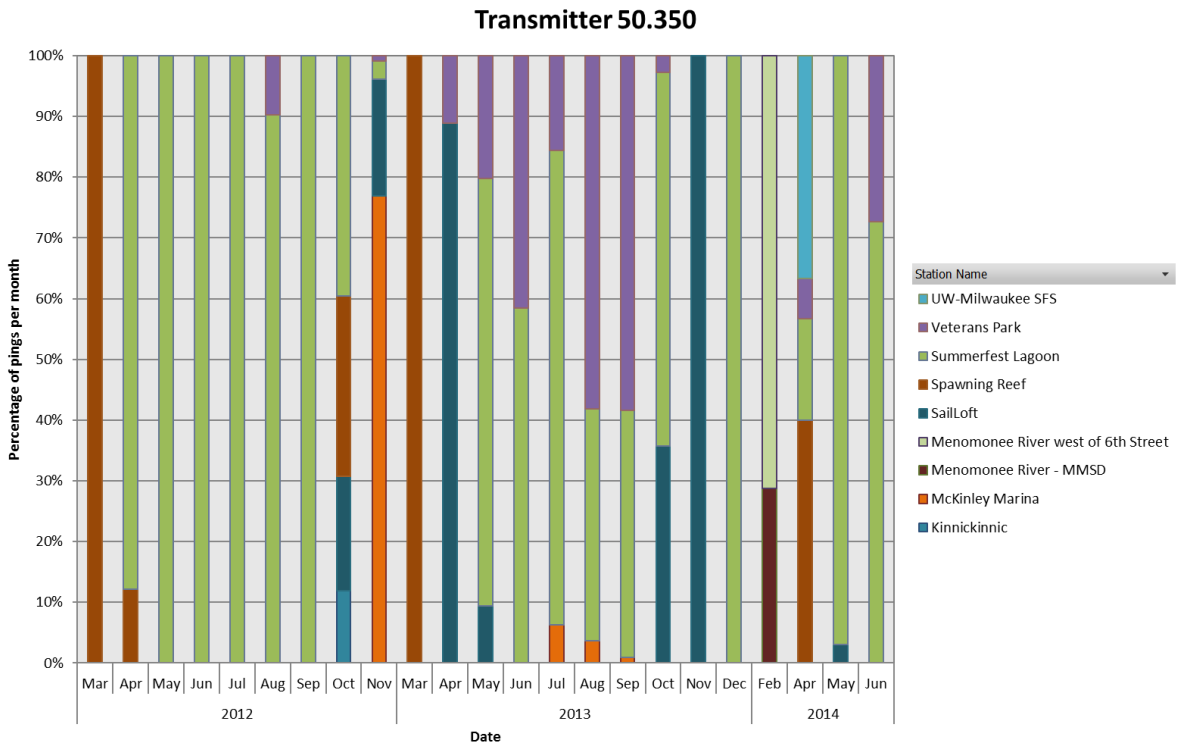

Figure 17. Movement of northern pike with transmitter 50.350 in 2012, 2013 and 2014.

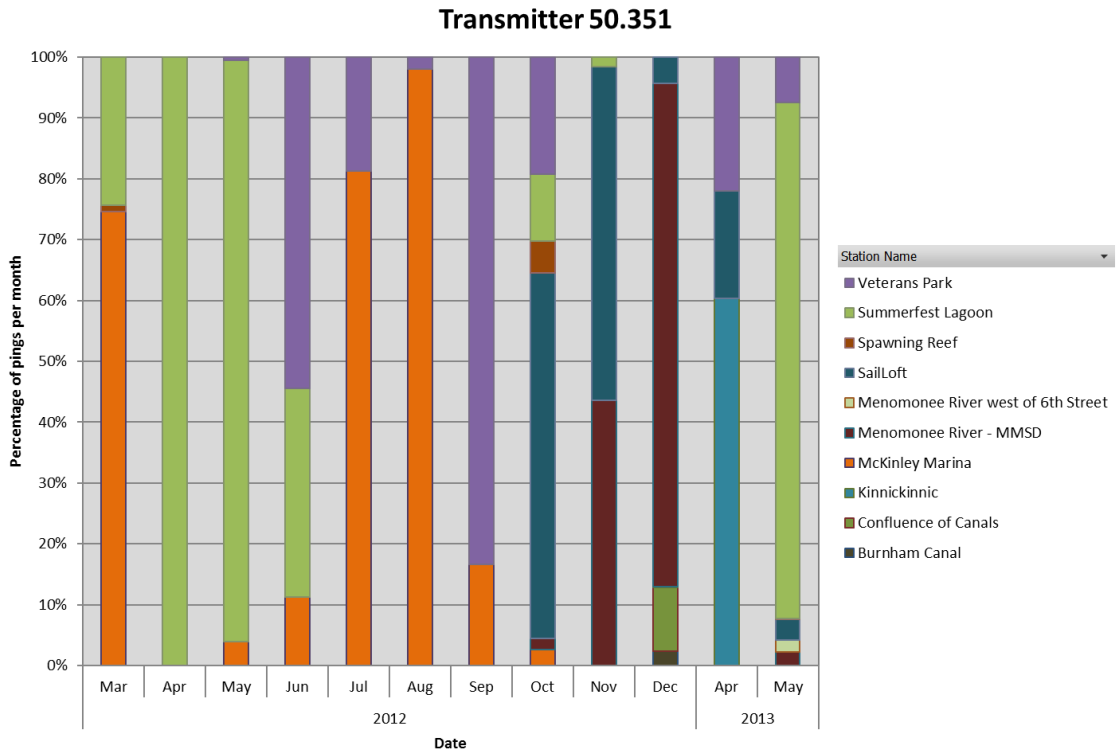

Figure 18. Movement of northern pike with transmitter 50.351 in 2012 and 2013.

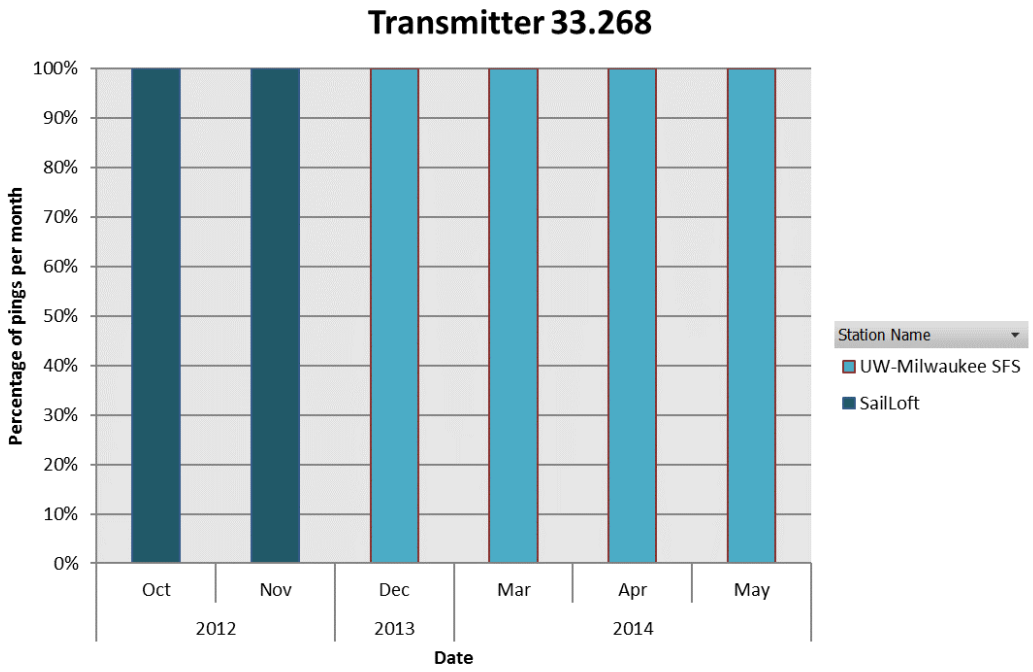

Figure 19. Movement of northern pike with transmitter 33.268 in 2012, 2013 and 2014.

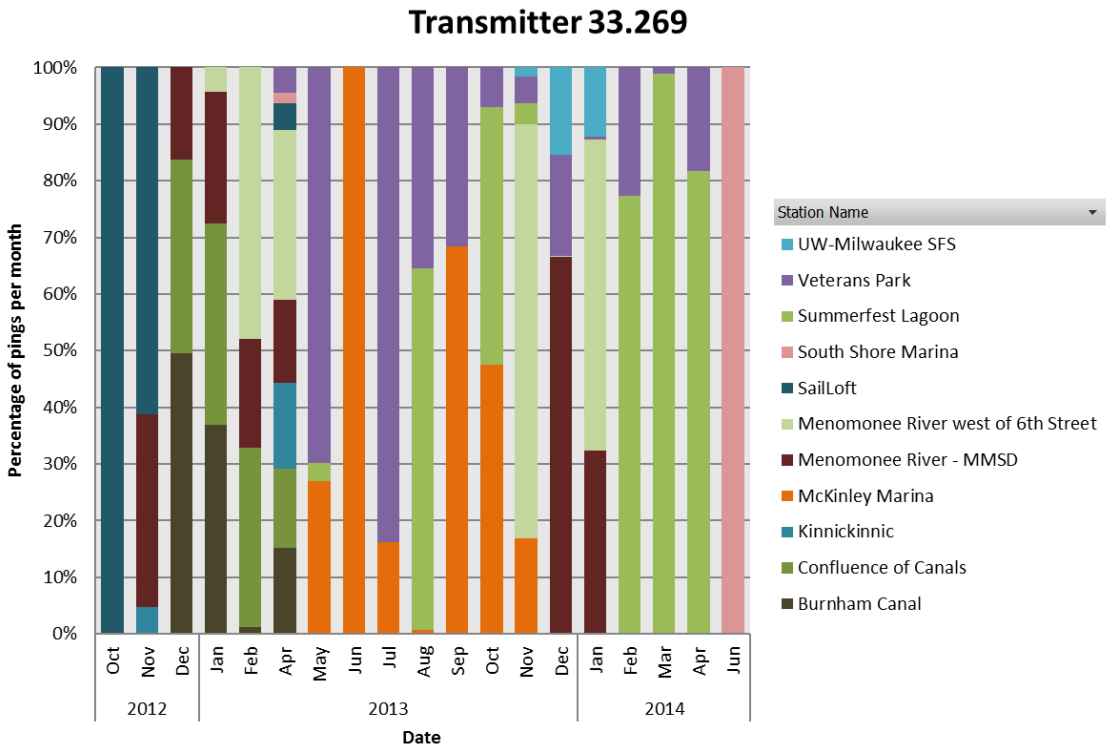

Figure 20. Movement of northern pike with transmitter 33.269 in 2012, 2013 and 2014.

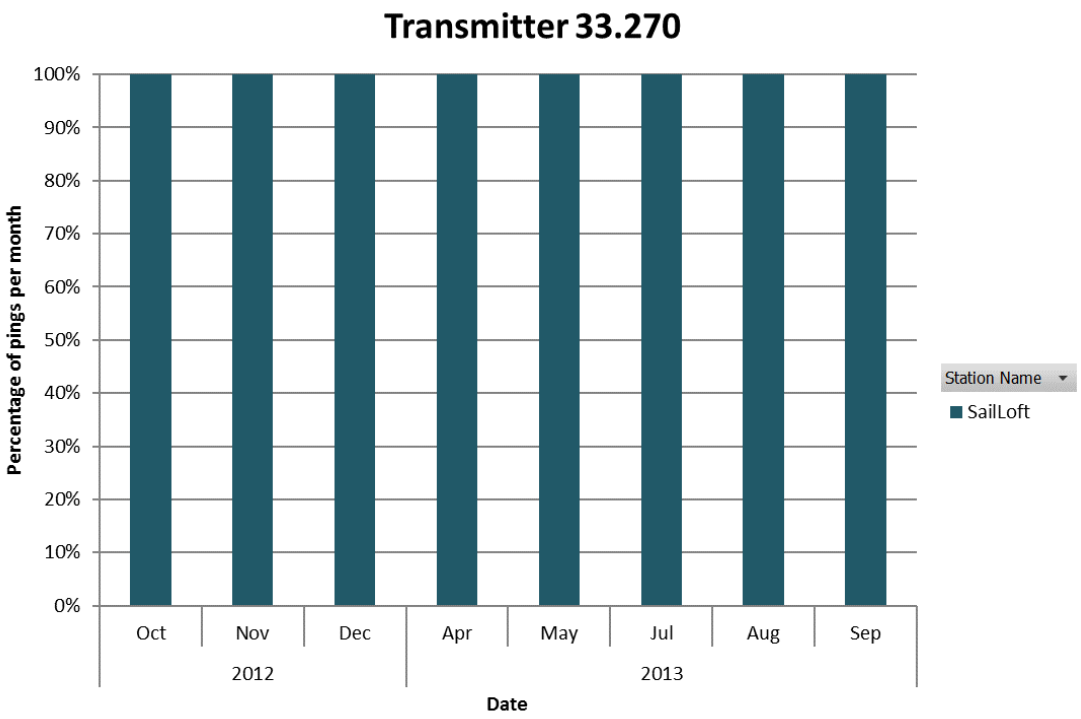

Figure 21. Movement of northern pike with transmitter 33.370 in 2012 and 2013

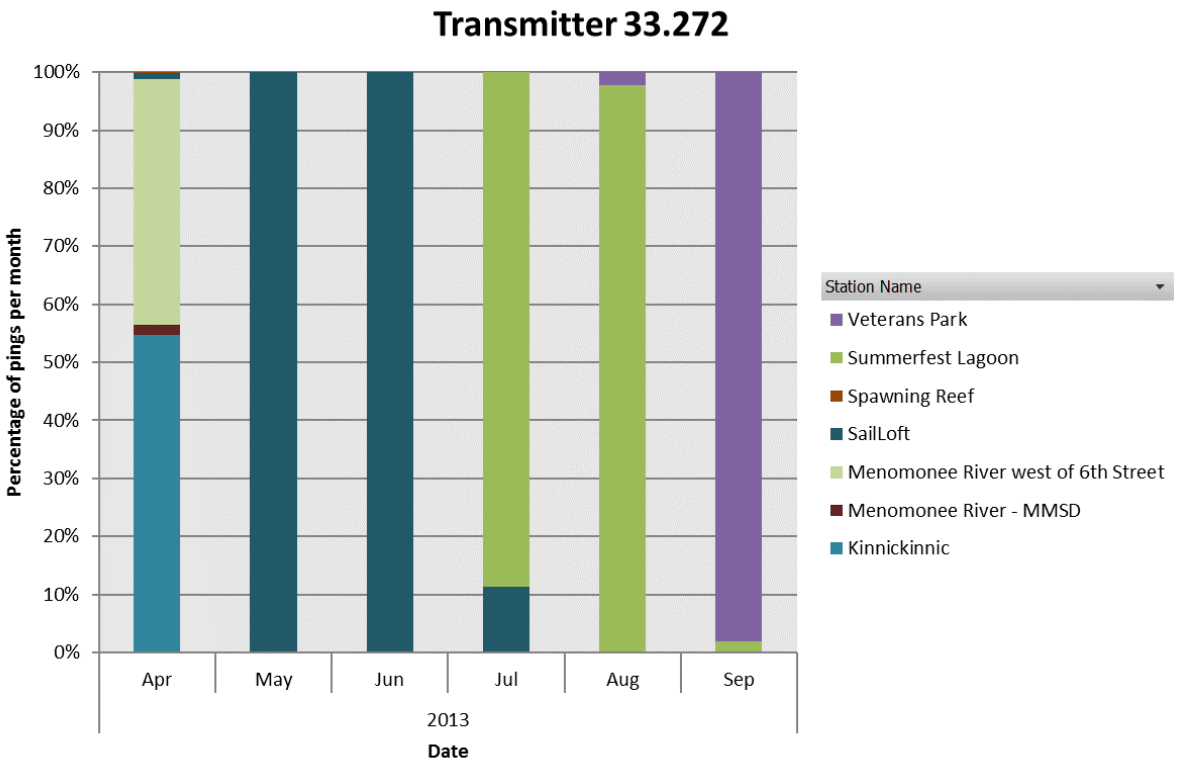

Figure 22. Movement of northern pike with transmitter 33.272 in 2013.

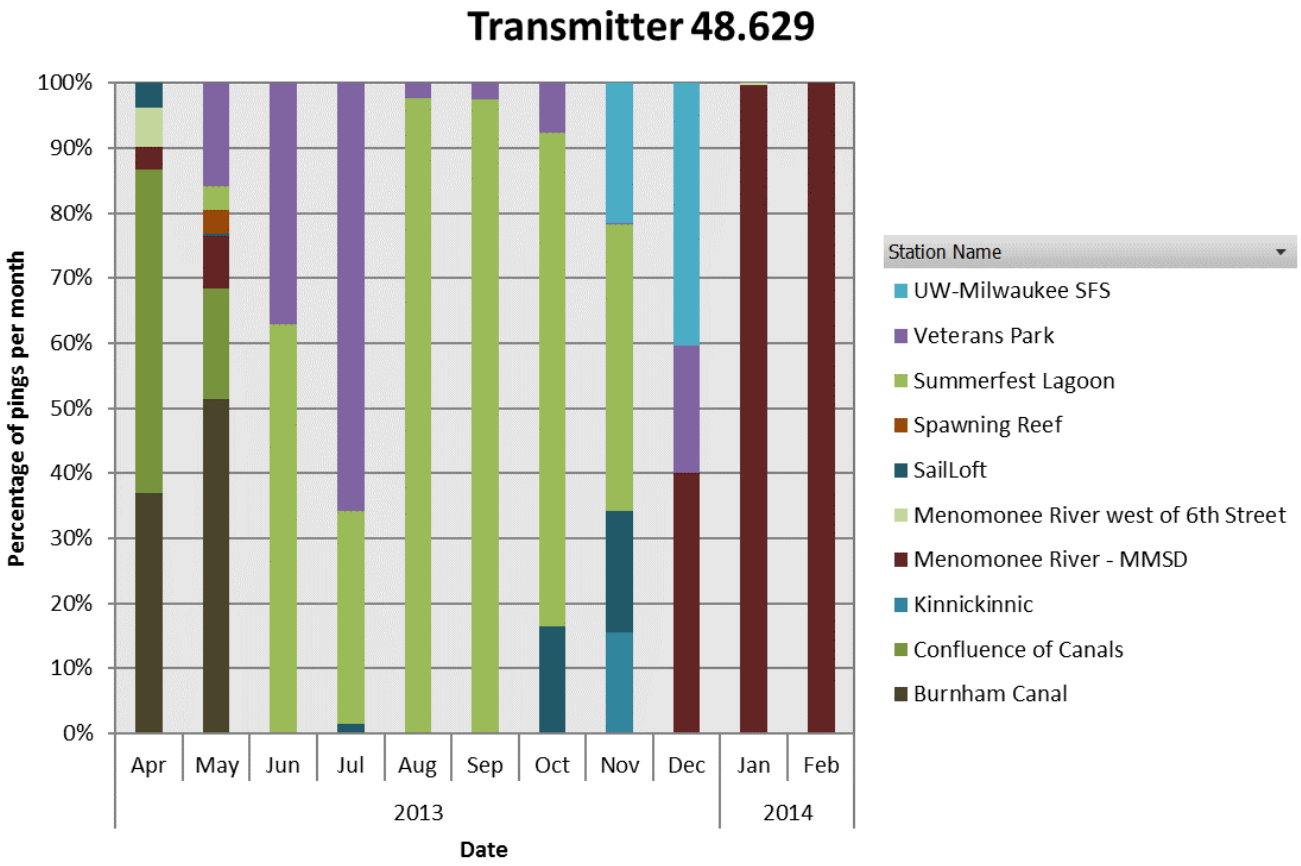

Figure 23. Movement of northern pike with transmitter 48.629 in 2013 and 2014.

References

P. Hirethota and T. Burzynski. 2013. Spring population assessment of northern pike and walleye in the Lower Milwaukee River and harbor – 2013. WDNR, Southern Lake Michigan Fisheries Unit. 4p.

Wawrzyn, W., WDNR. 2015. A Management Plan for Restoring a Sustainable Population of Northern Pike in the Milwaukee Estuary Area of Concern (AOC).

Appendix.

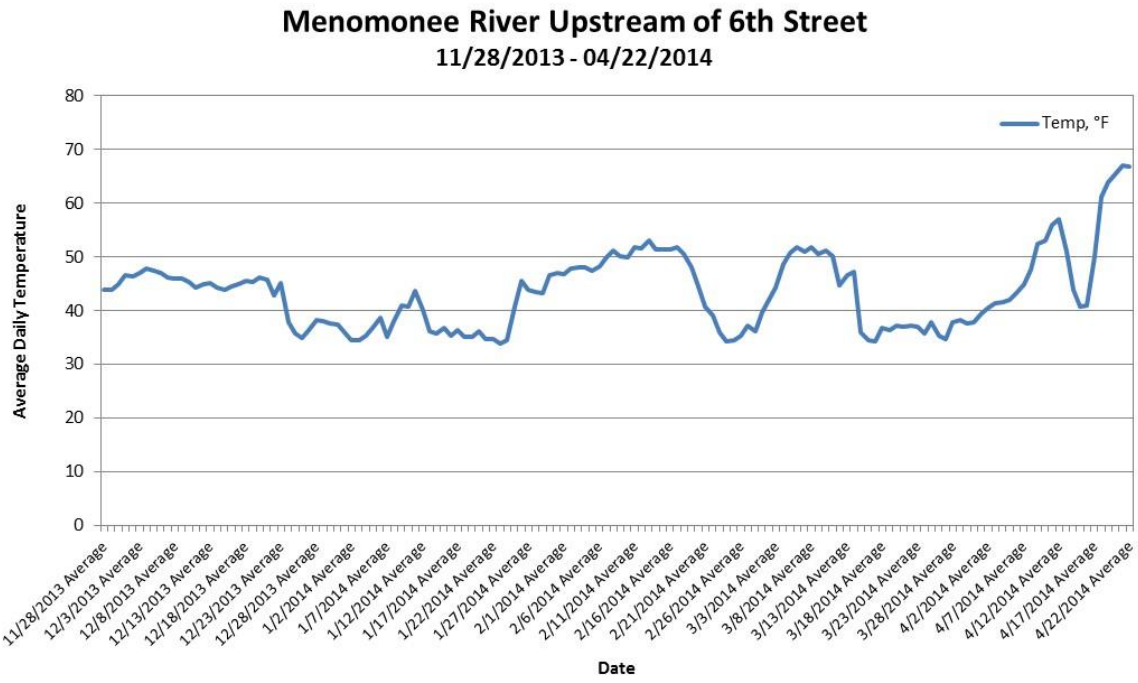

Figure A.1. Average daily temperature recorded using a thermistor at the Menomonee River upstream of 6th street.

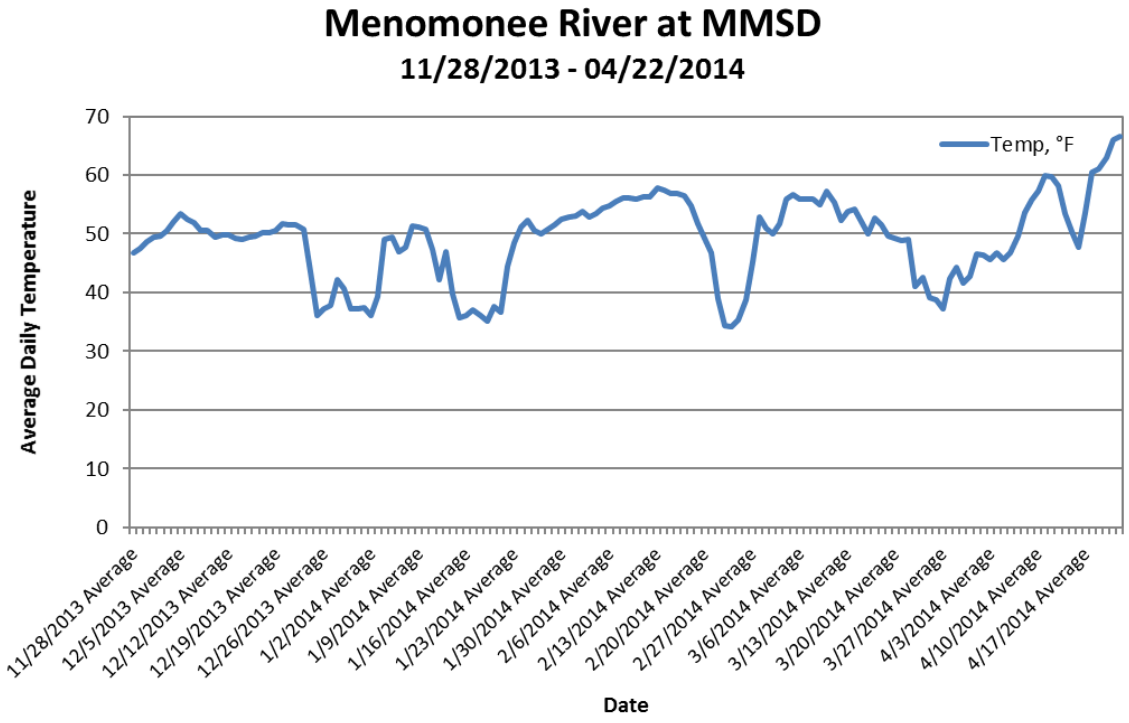

Figure A.2. Average daily temperature recorded using a thermistor at the Menomonee River MMSD location.

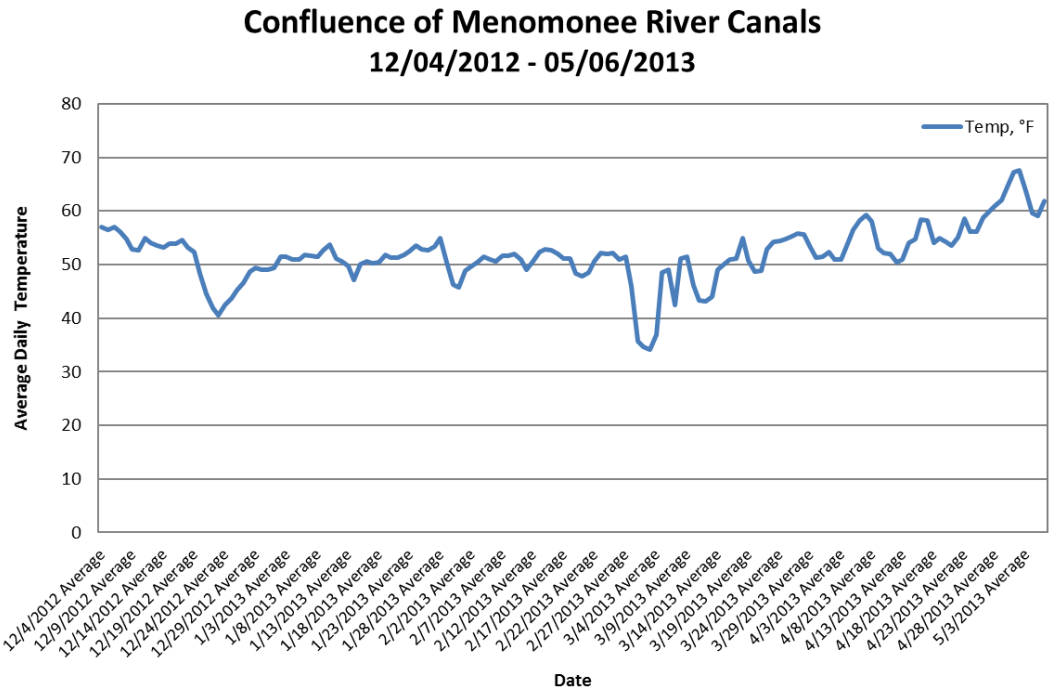

Figure A.3. Average daily temperature recorded using a thermistor at the confluence of Menomonee River canals.

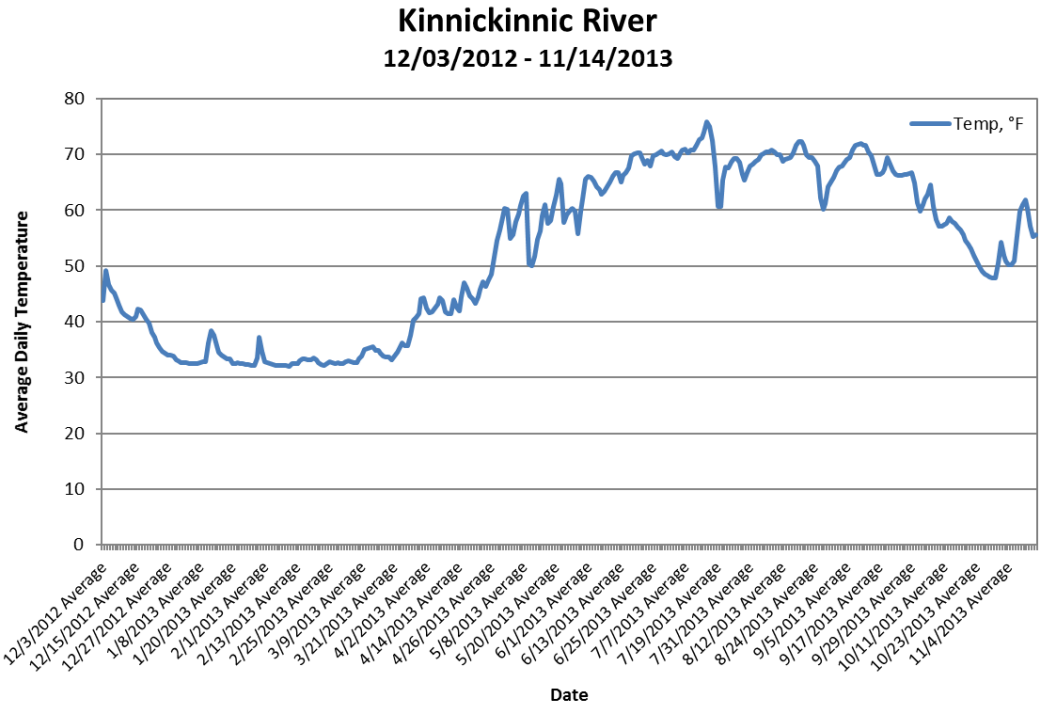

Figure A.4. Average daily temperature recorded using a thermistor at Kinnickinnic River.

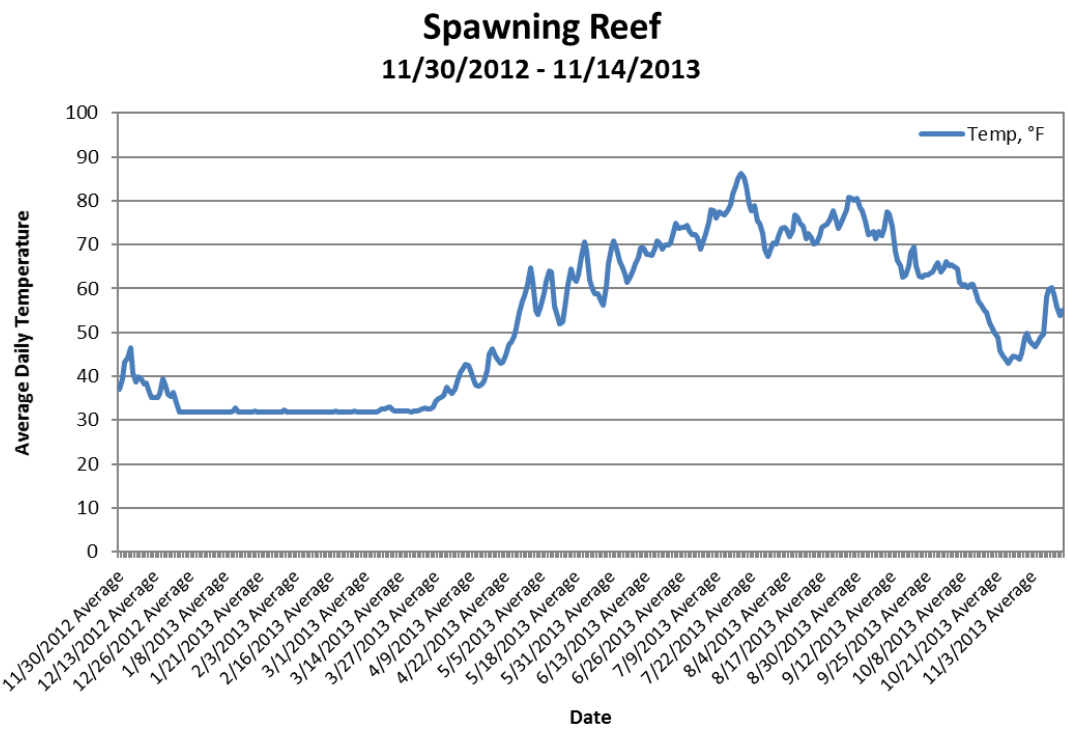

Figure A.5. Daily average temperature recorded using a thermistor at the spawning reef downstream of North Avenue dam.

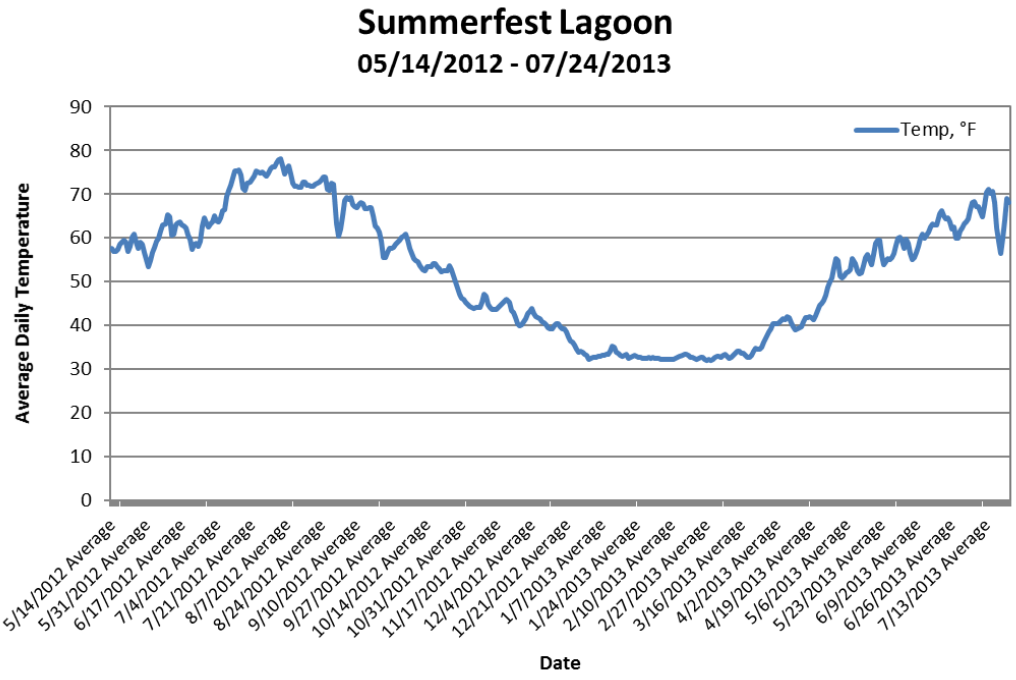

Figure A.6. Daily average temperature recorded using a thermistor at Summerfest Lagoon.

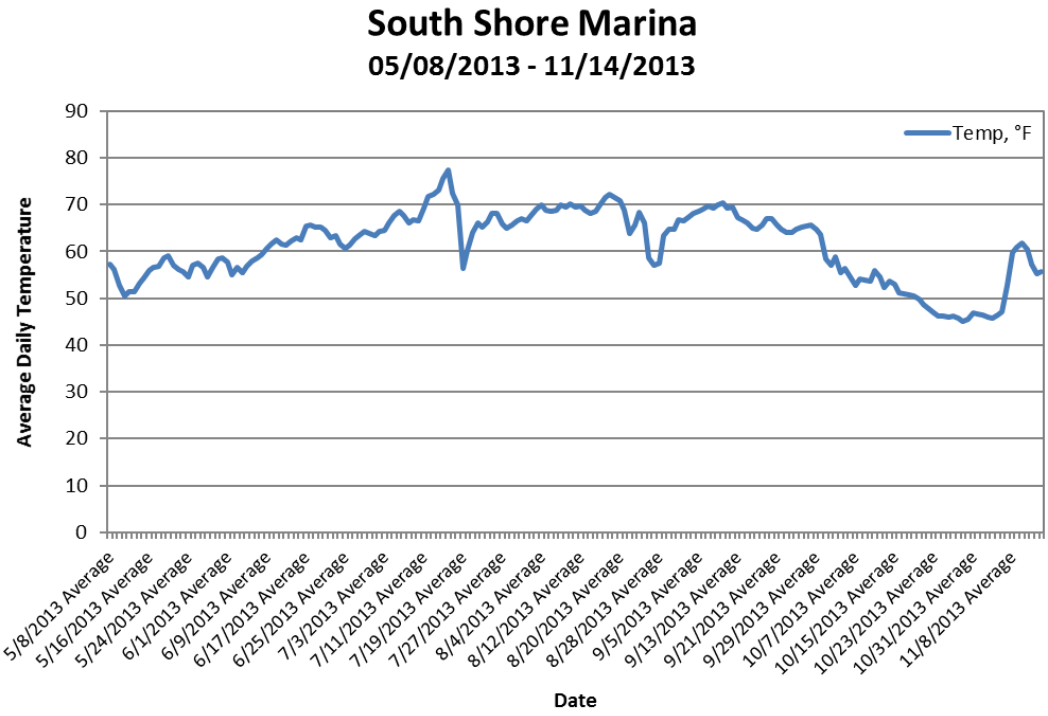

Figure A.7. Daily average temperature recorded using a thermistor at South Shore Marina.